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ECOLOGICALLY SUSTAINABLE ECONOMIC DEVELOPMENT:
KEY ISSUES FOR STRATEGIC ENVIRONMENTAL MANAGEMENT

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ECOLOGICALLY SUSTAINABLE ECONOMIC DEVELOPMENT:
KEY ISSUES FOR STRATEGIC ENVIRONMENTAL MANAGEMENT

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1. Prologue

The issue of a balanced development of our earth has been an intriguing research and policy question for several decades. The environmental problems emerging in the sixties and seventies have made us aware of antagonistic forces in the evolution of our socio-economic and environmental system. The dramatic changes - demographic, economic, social and technological - in the postwar period were not only purely quantitative in nature, but meant also a qualitative change in the structure of this system.

In view of these changes several disciplines have been stimulated over the past few decades to pay adequate attention to these issues. Out of some disciplines like economics or ecology even new sub-disciplines have emerged, for instance environmental economics, resource economics, environmental biology and resource ecology. In environmental economics the following issues were inter alia given special attention: pollution control strategies, evaluation of environmental damage, and macro relationships between economic growth and environmental policies. Resource economics on the other hand aimed at analyzing the economic aspects (e.g., cost-effectiveness) of extraction and use of natural (renewable and nonrenewable) resources. In environmental biology problems like impacts of eutrofication and micro pollution on organisms, populations and ecosystems are objects of analysis. Resource ecology paid inter alia attention to dynamic aspects of renewable resources in ecosystems (see for an overview Braat and van Lierop, 1987).

In the seventies it was increasingly recognized that mono-disciplinary research was not sufficient anymore for analyzing and modelling the complex issues mentioned above. Partial knowledge does not provide a policy relevant picture on complex interrelated systems dynamics, although it certainly succeeded in promoting public awareness regarding high policy priority for strict environmental restrictions on economic developments.

It is in the context of the previous remarks often argued that the morphogenesis affecting the face of our planet may also make our living and working environment intrinsically non-sustainable. Therefore it is conceivable that recently various attempts are being made at developing policy strategies for enhancing the sustainability of our earthly system.

The view that far reaching policy decisions are necessary in order to assure a certain level of sustainability for the earth as a whole is also reflected in a recent publication of the World Commission on Environment and Development, called 'Our Common Future' (the so-called Brundtland Report). However, the Brundtland Commission is also convinced that there are ways for a sustainable development of the world, and that the ability for future generations of need satisfaction can be reached without sacrificing essential needs of the present generations.

But there are also some basic requirements to reach such a situation. First of all, there should be a worldwide political will to attain a sustainable development. One cannot expect this will to exist in a wold of poverty, so that sustainable development requires an equity oriented policy. An adequate use of this will presuppose also a greater democracy in international decision-making. Sustainable development is not a fixed state of harmony but - in the view of the Commission - rather a balanced process of change (see also section 3). For our purpose it will be important to know the means for this balanced process of change (such that present as well as future needs may be satisfied). Those means are in the view of the Commission the exploitation of resources, the direction of investments, the technological development and institutional change. Thus it has become evident that the issue of sustainability is essentially much broader than that of environmental protection. Sustainability in this broader international context means a radical change in priority setting and policy agenda formation within the socio-economic en environmental policy institutions. Sustainability also needs a trans-sectoral planning structure and - given the globalization of environmental problems - an international alignment of policy. And finally, the notion of sustainability would also call for a more general (instead of a partial) and a more long-term (instead of a short-term) oriented policy perspective.

It is clear that the operationalisation of the notion of sustainability in this framework is fraught with many difficulties. In our present paper we will make a distinction between the economic oriented concept of development and the environmentally oriented concept of sustainability. Policy-makers usually regard these concepts as two extremes in the set of policy choice options. We will, however, argue that this is a misunderstanding and that a meaningful reconciliation of conflicting options is not a priori precluded.

For this purpose we will advocate here a goal-oriented approach as a useful methodological framework for analyzing economic development and ecological sustainability. The paper is organized as follows. In section 2 a brief overview of emerging environmental issues is given with the aim to provide some key elements for a useful analysis framework. Then in section 3 a more thorough description is given of a welfare theoretic approach with respect to the key issue of the present paper, viz. ecologically sustainable economic development. Next, section 4 is devoted to a description of analytical needs and limitations in the field of environmental policy analysis. This approach suggests the need to formulate important core research areas, to be explored in future research. This article is concluded with some prospective remarks.

2. Emerging Environmental Issues: The Need for an Analytical Framework

It is clear that conflicts between economic development and the environment are not vanishing. The impressive actuality of these conflicts often gives the impression that we are here confronted with a relatively new phenomenon in the history of man. Yet this is not true. Throughout history there have been periods where the socio-economic development was in conflict with the environmental potential for these developments. This confrontation was in the past often even more direct in the experience of mankind than this is the case in the present dynamic complex world. However, dynamics and complexity (including spatial interrelatedness) lead to real dangers regarding present environmental quality at a global scale.

Environmental issues come to fore in two cases, viz:

- if the socio-economic use of the environment exceeds some environmental potentials (i.e., the carrying capacity) for socio-economic development;
- if the need satisfaction of man is directly influenced by qualitative or quantitative environmental conditions.

Environmental potential refers to the ability - at a certain moment in time- of the environmental system to provide a sustainable support for socio-economic development. In this respect sustainable means that the productive and carrying capacity of the natural system involved can be maintained in the long run at least the same qualitative level (see for a more thorough description section 3). This first dimension of environmental issues is indirectly (through socio-economic processes) related to human welfare. The second dimension is directly related to the existing and developing levels of welfare. Nature conservation objectives, for instance, are often only relevant when primary needs like shelter, food and so on are fulfilled. Concern about the welfare positions of future generations is in this perspective to some extent a 'luxury' problem which however does not have to be of minor importance in a wealthy society (cf. Maslow's hierarchical needs structure).

We conclude that all environmental issues have in common that they influence human welfare. The actual and potential intensity of this welfare impact also justifies the policy relevance of these issues.

We have already mentioned several times the interwoven nature of economic-environmental issues. Scientist and policy analysts have the difficult task to provide decision-makers with essential information for proper decisions to be made. In principle, there are various ways to offer policy-makers the essential information. The first approach may be called the problem- or (aspect)-oriented approach. Here we have to transfer (selectively) information concerning some actual or potential issues of environmental relevance. This way of analyzing is especially useful when issues have already been identified and when policy decisions can not be postponed anymore.

However, for long term planning this approach is not satisfactory: firstly, this approach is lacking a system for identifying issues; secondly, this approach is not very fruitful in view of the dynamic interrelated nature of socio-economic environmental issues (solving one problem may bring about an other one); and thirdly, this approach does not give the opportunity for a balanced integrated policy judgement.

For this reason a second approach is more promising. We call this the goal-oriented approach. As we will show in section 3, identifying the policy objectives is a prerequisite for this approach. In line with the methodology of systems analysis we can picture a system around an objective or class of objectives. This methodology changes the task of integrated policy analysis, for then our prime concern is the dynamics of the relevant system instead of problem dynamics. Dealing with systems and subsystems necessitates to think about elements, to include the relevance in view of the objectives, the demarcation of systems boundaries, the prime forces of dynamics for this system, and so on (see section 3).
For instance, the transnational nature of environmental problems forms often a strong contrast with the local or national interests dominating environmental policies in many countries. Thus for an analytical purpose the boundaries seem to differ from those in an institutional one.

Clearly, a major problem consists of the local scale of environmental impacts emerging from global trends. This internationalization of environmental problems confronts us with qualitative (or structural) long-term changes at almost all places on earth (cf. Bartelmus, 1986). Fortunately, there is an increasing awareness that there is 'only one earth' (cf. the Brundtland Report). For example, an ongoing deforestation in (sub)tropical areas does not only lead to local erosion, but affects also the ecological basis and the climatological conditions at a much wider scale. Analogously, ozonization and greenhouse phenomena (caused by local fuel use of cars, electricity plants and industries) lead to a world-wide change in temperature and hence to dramatic environmental consequences. Thus the economy-ecology linkages embody a great diversity of external effects which are penetrating all components of our economic-environmental system (cf. Kallio et al., 1987 and Pearce, 1975).

Traditional economic approaches, such as marginal opportunity cost principles or shadow cost approaches in alternative accounting systems, neglect the externalities and in any case the qualitative shifts in dynamic economic-ecological systems. Besides, recent advances in the field of irreversible externalities (based inter alia on alternative discount rates for future generations) lack operationality, so that the actual causes of natural resource degradation cannot be coped with effectively in a conventional market system. In view of the global nature of these qualitative changes, which affect essentially all 'commons' of our planet, policies that can effectively tackle the real causes of environmental decay at a global scale are difficult to implement (Repetto, 1986).

In the recent past, already a variety of paradigms has been developed to take into consideration these dynamic processes (e.g. systems dynamics, 'zero growth' concept, 'eco-stability' idea or 'steady state' approach), but especially the linkage with actual deterioration of environmental conditions at a local or regional level is apparently difficult to establish. An integrating framework for economic and ecological processes is lacking so far, although the need for such a framework has been emphasized various times (cf. Myers, 1984 and Nijkamp, 1981).

It is worth noting that - although the past years have shown the necessity of a sound methodology for a coherent analysis of inter- and multidisciplinary issues - in the field of environmental economics such attempts are relatively rare and are, if they do exist, static in nature (or in a very limited sense dynamic).

Clearly, the pluriform nature of dynamic ecological and economic processes can in general hardly be described by means of conventional measurement models adopted in an isolated monodisciplinary framework. Coupling of phenomena or variables from rather different disciplines is in general hampered by differences in precision of observation, in spatial scale, in time perspective and in adjustment speed (see for a broader exposition Brouwer et al., 1985). The dynamic models in particular suffer from data constraints and the less reliable estimation methods themselves.

However, integrated environmental models may potentially be powerful instruments to analyze and evaluate changes in the (a-)biotic environment caused by human activities as consumption and production of goods and services, recreation, or environmental protection measures.

The interwoven relationship in a complex economic-environmental system has led to a variety of modelling attempts.

Initial attempts in this area can be found in the generalized (economic-ecological) input-output approaches developed among others by Isard and Leontief in the seventies. These models were static in nature and did not aim at depicting simultaneously a set of heterogeneous concepts on change processes, but served to provide a consistent accounting system (based on static equilibrium concepts). Apart from the static nature, the first generation of integrated environmental models was neither particularly appropriate for the analysis of concrete environmental policy issues such as land use planning, land reclamation, water resource planning, recreational planning or urban renewal.

From the late seventies onwards, various new attempts have been made to develop operational integrated environmental models in various fields of resource, land use and infrastructure planning. The interest in such analytical tools emerged from the growing concern among local and regional authorities about environmental quality. Furthermore, recent advances in the field of integrated systems modelling (based on computer sciences, e.g.) led also to an increase in the quality of suitable models for multidisciplinary purposes. Despite this progress, however, it is still true that the popularity of monodisciplinary environmental models (based on either economic or ecological principles, e.g.) is much higher than that of fully integrated environmental models. Attempts at integrating different model types are thus far still unsatisfactory (cf. Jansson, 1984, or Kemp and Lang, 1984).

We will briefly describe here some of the common model types (see fig. 1).

	static	dynamic
partial	(spatial-oriented) economic-environmental models, environmental evaluation models	dynamic stock flow models
complete	environmental input-output models	materials balance models

Fig. 1. A typology of economic-environmental modelling

The first distinction we make is between partial and complete economic-environmental models. The partial models represent environmental aspects of a part of an economic system, while the complete models try to represent an integral picture of a whole economy including (or focussing on) its environmental dimensions. The second distinction we use is that between the static and dynamic nature of the models. Of course, our typology is a simplification of the real modelling practice. There are for instance multi-level fully integrated land use models which can be situated in an entire row of the matrix, while some seemingly dynamic models - due to lack of data - may have more resemblance to static models.

We will briefly mention some shortcomings of these modelling efforts (see for a more extensive discussion Brouwer et al, 1984.

The (spatial-oriented) economic-environmental models have found many applications. For instance local land use (like recreation etc.) and energy models, (multi)regional production/pollution models, urban environmental quality models, etc. (see Brouwer et al., 1983, Spofford, 1976, and Lonergan, 1981). But in general these models are hampered by the following limitations:

- almost all spatially-oriented models are static in nature, so that they do not generate dynamic evolution patterns of intertwined economic-ecological systems;
- the majority of these models deals with pollution and land use aspects rather than with ecological processes;

- most of these models are unable to take into account drastic changes in the structure of the system (e.g., endogenous adjustments of technology), as they are usually based on a rigid input-output framework.

An inquiry carried out in 1982 at the Free University of Amsterdam showed that out of 200 multi-regional models only 50 were operational and only 3 were multi-regional economic-environmental models (Hafkamp, 1983).

Environmental evaluation models serve to judge the feasibility and desirability of alternative courses of action, based on political choice and plausibility criteria. Next to cost-benefit analysis in the late seventies a new class of evaluation models has been developed, namely the multiple criteria choice and evaluation models (see for a survey, among others, Nijkamp, 1980, Rietveld, 1980 and Voogd, 1983. The following remarks can be made regarding the content and use of such models:

- many of these models are comparatively static and hence not able to contribute to dynamic, sequential or procedural planning problems;
- the political basis of evaluation models characterized by multiple actors (parties, interest groups, multiple levels, etc.) is not very strong;
- the degree of acceptance of results achieved by means of evaluation models is sometimes low in the political arena, as many decision agencies prefer to keep many choice options open.

Input-output models, originally used for sectoral linkages, input requirements and deliveries of output at the production side of an economy, have also often been applied in environmental-economic research (see for instance Nijkamp, 1980). This framework was easily designed for the incorporation of emission of various pollutants and pollution abatement activities. Despite its popularity, the input-output framework has also several limitations, such as:

- it is based on linear production processes based on past data;
- input substitution (for instance, due to pollution abatement) is neglected;
- the vintage structure of new capital goods and the impacts of new

technology (including abatement) cannot be dealt with in the static framework of input-output analysis.

The dynamic stock-flow models in the right upper side of the matrix describe the trajectory of variables characterizing the structure and evolution of a part of the economy (e.g. the fishery sector) in relation to its environmental aspects. For this reason these models are usually partial in nature. Dynamic stock-flow models are in general hampered by various limitations, for instance:

- the majority of these models generate conditional pictures of the evolution of a certain sector, but fail to provide reliable predictions based on solid statistical-econometric techniques;
- these models usually fail to take into account consistency requirements with respect to national or global developments of all other sectors (e.g., dynamic additivity conditions in space and time);
- the behavioral character of many of these models is fairly limited: growth patterns are often generated by means of mechanistic time-dependent growth curves (e.g., logistic curves) without a clear linkage with behavioral choice patterns;
- the integration of policy measures and institutional configurations in such models is usually poor.

The last group of models we want to discuss here are the materials balance models. These models aim at providing a comprehensive picture of an economy by means of flows and stocks of energy and materials that are governed by physical-ecological principles (see Ayres and Kneese, 1969). Some limitations of this model are:

- its physical basis precludes an appropriate analysis of psychosomatic impacts of specific pollutants (e.g. toxic chemical compounds);
- ecological processes are in general neglected;
- various important economic aspects cannot be dealt with (the monetary part, societal processes, and so forth).

It has to be concluded that the ecological-economic linkage is indeed still fraught with severe analytical problems. Especially it has to be noted that many formal attempts at linking economics and ecology neglect the long-term dynamics of both economic and ecological systems.

This is once more regrettable as the long-term perspective determines essentially local and current environmental problems. Therefore, we will focus the attention on structural changes in such systems. This means that in particular the changes in systems parameters will be considered.

The foregoing observations imply the necessity to seek a coherent framework in which ecological processes are analyzed in relation to economic processes at a global-regional level. In the next section some key concepts, viz. economic development and ecological sustainability, will be discussed further. It is assumed that key factors of system developments (e.g. demography, technology, agriculture) influence both economic and ecological variables and determines the path of a potentially harmonious economic development and ecological sustainability.

3. Economic Development and Ecological Sustainability: Conflict or Compromise?

In many popular views, it is taken for granted that the relationship between economic development and ecological sustainability is usually conflictuous. Therefore, a closer analysis of these two concepts is necessary.

It is worth mentioning that the use of a formal welfare concept in economics may clarify some of these questions. This concept implies that all phenomena that - directly or indirectly - influence the utility level (or utility perception) of a person, group or society as a whole irrespective of the question whether or not they can be quantified in monetary terms - are to be regarded as arguments (or elements) of a welfare function, provided at least they involve a certain satisfaction of needs for scarce goods or services. This implies for instance that a beautiful park, a quiet environment, a nice cityscape or a unique mountainous area may all contribute to someone's welfare position. Seen from the perspective of a formal welfare theory, there is no conflict between conventional (economic) commodities (like a car or a house) and environmental commodities.

On the other hand, there are close mutual interactions between the traditional economic sector and the environmental sector. The construction of a recreational area or the production of a sewage technology has clearly many employment and income effects, while on the other hand the use of many commodities may affect the resource base of our economic-ecological system thus leading to environmental degradation.

Thus, in the short run there may be a conflict in terms of use of scarce commodities: more consumption of the one type may affect the availability of the other type, while both types have an impact on the individual or group's welfare position.

Seen from a long-term perspective, however, the question is whether a trajectory of economic development can be found that is in agreement with ecological sustainability. Both the economic system and the ecological system may go through a phase of structural change. Structural changes implies that not only the variables of the system are changing, but also the structure parameters (cf. Nijkamp and Soeteman, 1987).

The idea of structural vis-à-vis non-structural change is analogous to the distinction made by Tinbergen (1956) between quantitative and qualitative economic changes. Quantitative change refers to usual shifts, given a fixed parameter structure of the economy, whereas qualitative change refers to changes in the parameter structure itself. This means that the evolution of the system may exhibit various unstable trajectories (including bifurcations and wild fluctuations) before a new stable state is being reached. In systems analysis this is usually called morphogenesis. Examples of such structural changes in economics are: a total tax reform, a shift from an industrial structure toward a service-oriented structure, the use of a completely different production technology, or the introduction of a new institutional regime. Such situations of structural shifts in the economy are called economic development.

The same applies to ecological systems. Also ecological systems have morphogenetic properties, which might either disrupt an original state of the ecosystem or might induce a long-term regeneration process. If the ecosystem is able to reach a long-term stable situation which may be qualitatively different from the initial one, but which still assures a maintenance or improvement of the quality of the ecosystem in the long run, then this situation is called ecological sustainability. Examples of causes which may affect the ecological sustainability are inter alia: desertification and deforestation, extinction of key species in an ecosystem, ozonization, acid rain, and ocean pollution.

It is worth noting that sustainability encaptures the idea of stability, but only in a long-term perspective. The idea that an ecosystem should also exhibit a short-term stability is in contrast with the morphogenetic nature of ecosystems. In addition, this idea overlooks the possibility of cyclical behaviour and feedback reactions which might generate initial states. Besides, as all systems of earth are developing, a policy aimed at a short-term stability of an ecosystem might endanger a long-term sustainability of this system, as its resilience capacity with respect to other systems might decline.

One important remark has to be made here: certain structural changes may generate an irreversible process (or a reversibility against excessively high costs), especially in case of cumulative synergetic effects. From a socio-economic viewpoint of risk analysis, such situations would have to be avoided, if such irreversible processes would affect rare ecosystems. This idea may provide a guideline for environmental policy: the long-term qualitative evolution of an economic-environmental system should - through irreversible processes - not lead to an extinction of relatively rare (parts of) the ecosystem.

The latter idea is in agreement with the view of Ciriacy-Wantrup (1925, p. 253) on safe minimum standards of conservation. In his opinion such a standard is to be achieved by avoiding the critical zone - that is those physical conditions brought on by human action, which make it uneconomical to halt and reverse depletion.

Consequently, in terms of long-term oriented environmental research three focal points have to be emphasized:

(1) the identification of key forces (internal and external) which act as driving forces for qualitative changes;

(2) the identification of surprises in the dynamics of complex systems (i.e., bifurcations or singularities in non-linear dynamic

systems);

(3) the identification of feasible boundaries for the long-term evolution of a compound economic-environmental system within which mainly qualitative but reversible change processes take place (i.e., long term sensitivity and risk analysis).

It is evident that in this context we are facing a great many shortcomings in the area of environmental economics. Clark (1986, p.11) has stated in this respect:

> ".... we have learned just enough about the planet and its workings to see how far we are from having either the blueprints or the operator's manual that would let us turn that diffuse and stumbling management into the confident captaincy implied by the 'spaceship' school of thought".

Finally, it is evident that the previous notion of ecological sustainability is not a system's objective; it is not internally imposed by the ecosystem, but it is the result of a risk strategy adopted on the basis of the value systems of the homo economicus (cf. Wynne, 1987 and Kleindorfer and Kunreuther, 1987). In other words, introduction of 'sustainability' as part of our welfare concept makes clear that we are not dealing with a term only related to biological and geo-chemical-physical environment, but - like economic development - also to the value system of man. This is an important point, as the use of this concept also presupposes an answer to the question of the purpose for which we need sustainability. What kind of need satisfaction is involved? However, given societal wants and norms it will be clear that the issue of sustainability will become more important with an increasing intensity of threat, an increasing spatial and time scale of the impacts, and a higher degree of irreversibility of the impacts.

This also explains why in actual policy terms the notion of ecological sustainability is usually conceived of as a latent variable, which may be operationalized by means of observable indicators such as carrying capacity, sustainable yield, resilience, etc. These proxies will briefly be described here (cf. Cozijn, 1986).

- sustainable yield: this concept is related to a control strategy for renewable resources in which economic benefit objectives preclude an exhaustion in the long run. It is a well-known strategy in forestry and fishery management models.

- carrying capacity: this concept refers to the level of activities of a certain species that can in the long run be maintained given the regional resources. It is a well-known concept in predator-prey models (see e.g. Bishop et al., 1974, and Vincent, 1981).
- resilience this concept refers to the vulnerability or the self-adjustment of an ecosystem; within certain limits a stable growth may occur, but beyond a threshold level a bifurcation may emerge forcing the system to move to a qualitatively different level. In this framework risk assessment models may be helpful (cf. Brooks, 1986).

All these measurable indicators reflect, in the framework of the biosphere, the potential of an ecosystem to maintain or enhance its long-term flexibility or resilience with respect to exogenous changes in key factors. Examples of a sustainable development are thus recycling and ecodevelopment, while examples of a non-sustainable development are the use of pesticides, monocultures etc.

In the framework of a long-term formal welfare concept - as a unifying scale of need satisfaction of scarce resources - we can thus argue that both a sustainable ecological development and a qualitative progress in economic development contribute to an increase of individual or societal long-term welfare (see figure 2). It has to be added however that the measurement of such long-term welfare changes is problematic, as it neglects usually in a monetary evaluation system the social costs emerging from environmental deterioration and as it cannot provide a full representation of the processes behind resource dynamics and the provision of environmental services (cf. Gilbert and Hafkamp, 1986).

Thus, in a long-term framework the global trends cause local impacts which can hardly be incorporated in the usual market and price mechanism, so that unbalanced decisions are likely to emerge. For instance, the construction of a swimming pool at a certain place (meant as a structural compensation for dirty surface water caused by polluting activities upstream) leads in our usual accounting system to a rise in GNP, whereas this should from an environmental viewpoint be regarded as a structural cost component.

In this context, it is interesting to observe that Janicke et al. (1987) found - in a cross-comparative study among 31 countries - a positive relationship between income on the one hand, and pollution and resource use on the other; a negative relationship between the growth on GNP and that of environmental decay in economies with a well developed sector structure; and a positive relationship between the growth of GNP and the growth of environmental degradation in countries with a poorly developed sector structure.

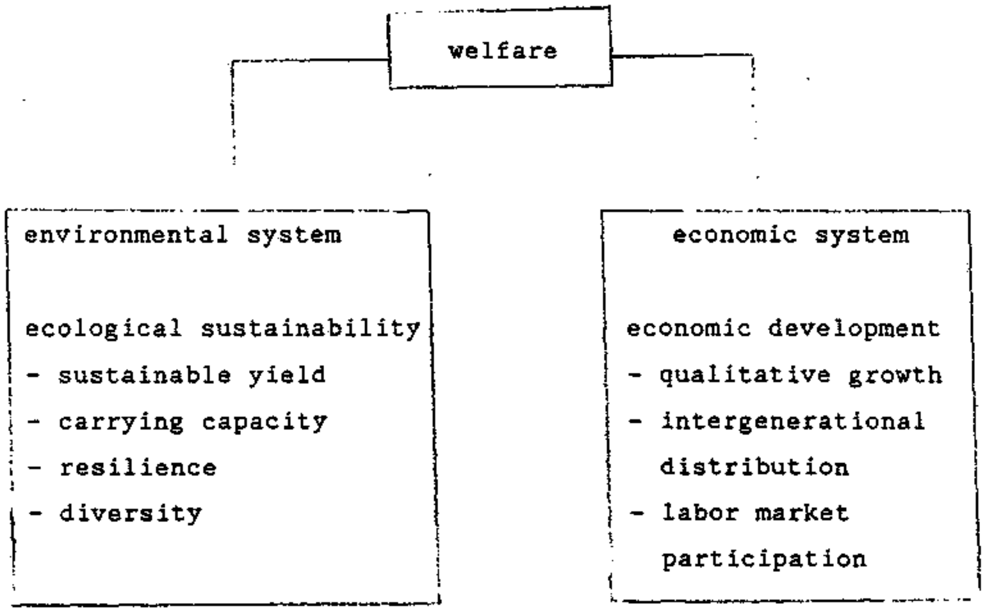

Fig. 2. Determinants of a long-term welfare profile.

Thus also our paper underlines the idea of the Brundtland Commission that economic and environmental development are not necessarily contradictory issues.

4. Need for Future-oriented Policy Analysis

In the previous sections much emphasis has been placed on long-term structural changes in economic-environmental systems. Although a wide variety of economic-ecological models has been developed (see for a review Braat and Van Lierop, 1987), the majority of them has - in light of a long-term orientation - several severe flaws and limitations, such as:

- the global models from the 1970s appeared to be too less detailed to describe policy-relevant developments at a national or regional scale, so that their relevance was too low to support actual policy decisions;
- micro-analysis of individual behaviour of actors is interesting, but does not provide sufficient insight into compound long-term societal reaction patterns;

- the complicated and manifold long-term feedback relationships from the environmental to the economic system are often neglected;
- the majority of quantitative modelling efforts has an extremely weak data base, so that their validity is still questionable.

It is worth noting here that seen from a policy angle in a long-term planning context there is in general less need for a precise prediction of parameter values and of subsequent values of variables, but much more for the above mentioned identification of key factors, surprised and feasible boundaries of a compound dynamic economic environmental system. This also implies that in various cases it is more important to know the direction of variables (i.e. the sign of movement) than their quantitative values (which are in the long-run in any case questionable). In this respect the use of qualitative calculus may be an adequate instrument (see Brouwer, 1987).

Given the previous remarks, there is definitely a need for more meso-oriented models (in terms of spatial scale, economic detail and ecological information) which are able to generate and to display a set of feasible developments within certain boundaries set by economic possibilities and ecological desirabilities.

To operationalize such models conventional econometric-statistical technique would no doubt fail due to lack of any quantitative information on qualitative shifts, so that in this case it makes more sense to use expert views - preferably experts with contrasting views - to analyze the key factors, surprises and feasible boundaries of long-term development.

Now the question is: which issues are of crucial importance for long-term structural developments seen from the viewpoint of environmental economic policy. This question can be clarified by examining the following interaction matrix between three components, viz. environmental evolution (EE), economic development (ED) and environmental-economic policy (EEP).

	EEP	EE	ED
EEP		o	o
EE	o		x
ED	o	x	

Fig.3 An environmental-economic interaction matrix.

From a purely analytical perspective, especially the entries x and x are relevant, while from a policy perspective mainly the entries o are relevant. Consequently, in the context of integrated analysis of economic development problems and ecological sustainability problems, especially the issues focussing on interactive relationships are to be dealt with (particularly if they have a future orientation).

Clearly, it is possible to mention a great many topics which are interesting for such a strategic future-oriented analysis. To arrive at a coherent and systematic analysis, a meaningful first step of such an analysis is to make an appropriate listing of various research issues, based on ideas and suggestions of various experts.

Next, a set of selection criteria may be specified in order to identify the most relevant issues. Examples of such selection criteria are: the relevance for policy-makers, the potential for generating solutions, the extent to which gaps in knowledge ar filled, the importance for other actors (e.g., industry), the possible emergence of synergetic cumulative effects, the degree of theoretical/methodological innovativeness, the inclusion of the interest of next generations, etc.

By means of a confrontation of the long list of possible research issues with the above mentioned set of selection criteria, a limited set of core research areas focussing on an ecologically sustainable economic development may then be identified. Examples of such core research areas are:

- a comparative study (in different countries or regions concerning the structural impact of environmental policy on a limited set of key factors which are regarded as relevant for the evolution of both the economic and the environmental system. Examples are the development of the energy sector or the chemical industry.

- an analysis of the consequences of the dynamics in a regional environmental system for a potential regional economic development. A good example would be here the long range impact on land use planning (including agriculture and forestry).
- an analysis of those parts of the rapidly evolving technological system which have important influences on both the economic and the environmental system.

Such core research areas would than be the fields which have to be explored more thoroughly from the viewpoint of long-term dynamics.

5. Prospect

Ecology and economics are by definition not a pair of disciplines which have developed a compatible methodology or analytical framework, as the presuppositions of these disciplines are to a large extent different. However, this does not imply that the foundations of these disciplines are completely in contrast with each other. Especially if one adopts a long-term perspective, it becomes clear that ecological deterioration means a threat to economic progress vice versa. Therefore, the idea of an ecologically sustainable economic development is not an illusion, but can be justified from both economic and ecological principles. But it is essential in this context that conventional analytical tools (e.g., linear trend extrapolation) are abandoned and that creative programme design by experts (based on e.g. the analysis of key factors, surprises and boundaries) receives much more attention in both scientific research and environmental policy analysis.

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